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ABSTRACT

This review of the literature on computer assisted instruction (CAI) focuses on the use of CAI with grades K-13, and specifically assesses the relative merits of traditional instruction and CAI in promoting student achievement. Also assessed are the applications of CAI in the area of special education. Three types of reviews are used exclusively: (1) subjective, personal opinion; (2) box score reviews, in which the author gives narrative comments about the studies and reports the proportion favorable to CAI; and (3) meta-analysis, which uses objective procedures to locate studies, quantitative methods to describe study features and their outcomes, and statistical methods to summarize overall findings. The document includes an account of the method of locating studies (the ERIC, Psychological Abstracts, Ontario Educational Resources Information System, and Exceptional Child Educational Resources databases), a description of the document review, definitions, and the problems of terminology. Five major reviews are included: Vinsonhaler and Bass (1972); Edwards, et al. (1975); Burns and Bozeman (1981); Kulik, J. et al. (1983); and Kulik, C. C. et al. (1984). The paper concludes with six generalizations based on the five reviews and a discussion of the future of CAI use, which includes some recommendations. A five page bibliography is attached. (JB)

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COMPUTER ASSISTED INSTRUCTION:
A REVIEW OF THE REVIEWS

R. G. Stennett, Ph. D.

Research Report 85-01

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COMPUTER ASSISTED INSTRUCTION: A REVIEW OF THE REVIEWS

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The terms of reference for this review of the literature on computer assisted instruction (CAI), dictated to a significant degree by limitations of time and money, were as follows:

(1) The review should be limited to CAI or computer assisted learning (CAL). CAI overlaps with and is sometimes subsumed by systems of computer managed instruction (CMI). This review is, therefore, not concerned with programs to develop computer awareness, students' use of computers as a tool, computer studies courses or students' learning to program computers.

(2) The focus of the review was to be on the use of CAI with Kindergarten to Grade 13 students. The primary interest was in assessing the relative merits of traditional instruction (TI) and CAI in promoting student achievement. Applications of CAI in the area of special education were also to be assessed.

(3) To the extent possible, the review was to be limited to CAI programs based on micro-computer hardware.

(4) Because of the restrictions of time and money, this review had to depend almost entirely on three types of reviews conducted by other authors: (a) subjective, personal opinion type reviews (b) box score reviews, in which the author gives narrative comments about the studies and reports the proportion favourable to CAI and (c) meta-analyses. (Meta-analysis, a kind of analysis of the analyses, involves using objective procedures to locate and edit studies, quantitative methods to describe study features and their outcomes and statistical methods to summarize overall findings.)

This review of the literature on CAI is, therefore, primarily a review of the reviews.

Method

Locating studies

Computer searches, focused by the terms of reference of this review, were made of four data bases: Educational Resources Information Centre (ERIC), Psychological Abstracts (PA), Ontario Educational Resources Information System (ONTERIS) and Exceptional Child Educational Resources (ECER).¹

¹ The author would like to thank Mrs. Rosalind Moorehead of the Educational Leadership Centre at Althouse College for conducting these searches.

In addition, inquiries were made by phone or mail to individuals in Ontario thought to have expertise or conducting research in CAI. These inquiries were directed toward consultants in our own system and professors at the University of Western Ontario, Althouse and Queen's Colleges of Education and the Ontario Institute for Studies in Education. Letters were also sent to authors of two or three promising papers that could not be readily obtained locally.

Document Review

Using the techniques outlined, 68 reports of potentially relevant studies were located. Of that number, only five were detailed critical reviews of empirical research studies on the relative effectiveness of CAI (Visonhaler & Bass, 1972; Edwards et al, 1975; Burns and Bozeman, 1981; Kulik et al, 1983; Kulik et al, 1984). Unfortunately, these reviews are not completely independent. For example, 8 of the 10 studies reported by Visonhaler and Bass are also included in the 33 studies reviewed by Edwards et al. Two of the major meta-analyses contain no list of studies reviewed so that it is impossible to determine the degree of overlap in coverage. The various reviews, therefore, are not completely independent and tend, to an unknown degree, to build upon one another. The generalizations presented later in this review are, however, based primarily on the findings of these five reviews.

A complete list of all studies consulted for this review is appended to this report.

Definitions

CAI, a subset of computer based education (CBE), is usually regarded as including four basic types of activity:

(1) *Drill and Practice*, in which the computer provides practice exercises as a follow-up to teacher presentations; (2) *Tutorial*, in which the computer both presents the concepts and provides practice exercises; (3) *Dialogue*, in which the computer presents both lessons and practice exercises, and in which the student can ask questions and control the sequence of learning, and (4) *Computer-managed instruction (CMI)*, in which the computer evaluates students performance, guides students to appropriate instructional materials and keeps detailed records. Some writers also include, under the rubric of CAI: (5) *Simulations*, in which the computer is used to simulate or generate environments that could not otherwise be made available and (6) *Problem Solving*, in which students use the computer to help solve problems and, in this process, enhance their general problem-solving skills. Some complex CAI systems include combinations of these functions, e.g., tutorial and CMI.

Different authors use the terms CBE, CAI and CMI in different ways. Some, for example, do not include CMI as a subset of CAI but regard CAI as one possible component of a CMI system. Other authors regard CMI simply as a computer-based variant of individualized instruction.

Problems

According to Suppes and MacKen (1978) the earliest CAI venture in

a public school setting took place in 1965. Since that time almost all significant CAI efforts have been based on a hardware configuration consisting of a mainframe supporting a varying number of terminals. Many of these projects have also involved sophisticated CMI procedures. The micro-computer first appeared in 1975 and did not receive widespread use until the early 1980s. There is, therefore, little research literature on micro-computer based CAI and we were unable to find any review of such studies. However, the capacity of micros is increasing so rapidly that, in the near future, they may be able to duplicate the performance of the mainframe-terminal configuration. In any event, the reader should bear in mind that any generalizations about the relative effectiveness of CAI assume the capabilities of a mainframe-terminal configuration. It should also be borne in mind that recent advances in technology have greatly extended the range of input and output options available and this, in turn, may serve to heighten the power of CAI.

Considering the current extent of CAI activity, there is a relative paucity of well designed, controlled studies and the great majority are limited to drill and practice and tutorial type applications.

The effectiveness of CAI obviously depends heavily on the quality of the software employed and, to a lesser extent, on the adequacy of the associated implementation and management processes. Few studies, and only one of the reviews, describe or document these variables. In fact, one of the major shortcomings of CAI research is a failure to identify those components of CAI that are critical to its success.

In most projects CAI has been used as a supplement to regular instruction and, as a result, the achievement of students given regular instruction is compared with that of students having regular instruction *plus* CAI. Only a few studies attempted to equate student groups for total instructional time. It is, therefore, difficult to determine whether the relatively superior performance of CAI instructed students is due to the use of CAI or simply additional instruction.

As with any new instructional delivery system there is always the possibility that the improved performance of students simply reflects the Hawthorne effect, i.e., an improvement produced by novelty, increased enthusiasm or motivation rather than by the delivery system itself. Few studies included controls for this possibility.

Although there are many reports of imaginative attempts to employ CAI in the special education area, there appear to be very few, if any, carefully controlled studies. We were unable to locate a critical review or meta-analysis of work in this area, despite the fact that several authors report CAI to be relatively more effective with lower ability or disadvantaged students.

There is a general consensus of experts in the CAI area that the major limiting factor in further development is the lack of high quality software, which is also seen as the most difficult and costly problem to overcome.

In summary, then, the research available in the area of CAI is sparse, relatively weak, and quite limited in scope. Since no studies were located which evaluated micro-based provision of CAI, its probable impact will have to be inferred from the results of studies using the mainframe-terminals hardware configuration and some judgments about the extent to which micros can duplicate the performance of that hardware.

The Five Major Reviews

Vinsonhaler & Bass (1972)

These authors reviewed ten studies published between 1966 and 1970. All studies involved CAI drill and practice (D & P) in grades 1 to 6 in the areas of mathematics or language arts. CAI was used as a supplement to traditional instruction (TI) with standardized achievement tests as the outcome measures. Supplemental CAI was provided for 5 to 15 minutes daily over periods ranging from 3 to 10 months.

In almost all comparisons, CAI students made greater achievement gains in both language arts (.1 to .4 G.E. (grade equivalents)) and mathematics (.0 to .88 G.E.) than students receiving only TI. Although figures are not supplied the authors state that the majority of differences found were statistically significant.

Edwards et al (1975)

This box-score type review, covering 33 studies published between 1966 and 1973, provided no information on the results of tests of statistical significance.

In all 10 studies comparing CAI as a supplement to TI, students receiving CAI gained more in achievement than students receiving only TI. Five of these studies involved CAI D&P in arithmetic with students in grades 2 to 6 and three of the five studies were the same as those reported by Visonhaler & Bass.

In 20 studies in which CAI was used as a substitute, in whole or in part, for TI, 9 studies showed better achievement for CAI students, 8 found no difference and 3 showed mixed results. These studies covered a great variety of subject areas and grades from one to college.

In nine studies, involving tutorial or simulation CAI, students took less time to learn and their achievement was either equal to or greater than that of students given TI.

Two studies involving CAI D&P for elementary arithmetic found relatively greater gains for low ability students.

Burns and Bozeman (1981)

This meta-analysis, covering 40 studies done before 1981, concentrated on the supplementary D&P and tutorial CAI only in the area of mathematics and only for elementary and secondary level students.

Meta-analysis employs a common measure of treatment effectiveness called "effect size" (ES) to obtain a quantitative synthesis of study findings. Effect size is calculated as the difference between the outcome variable means of the treatment and control groups, divided by the standard deviation of the control group. The average or mean values of ES taken across a series of studies is then used to characterize the overall effectiveness of the treatment under study. Since ES is a measure of change reported in standard deviation units, the traditional guidelines for judging the educational significance of a finding can be used. That is, any ES of .25 or greater is considered to be of educational significance. In test score terminology this represents a shift from the 50th to the 60th percentile or greater.

An overall mean ES of .34 was obtained for D&P CAI and .45 for tutorial CAI, thus indicating an educationally significant advantage for CAI supplemented mathematics instruction over TI.

Supplementary D&P CAI was found to be somewhat more effective at elementary (Mean ES = .35) than secondary (Mean ES = .24) levels and probably also for disadvantaged students. There is some suggestion that boys may respond more favorably than girls.

Supplementary tutorial CAI is effective at both elementary and secondary levels (Mean ESs of .43 and .52 respectively) and may also be somewhat more effective with disadvantaged students.

Kulik, J. et al (1983)

This meta-analysis integrated the findings from 51 studies on computer based teaching in grades 6 through 12. All studies reviewed involved control groups and any with 'crippling methodological flaws' were excluded. The studies were concerned to varying degrees with the effects of CAI on six student outcomes, viz., final examination performance, retention examination performance, attitude toward subject taught, attitude toward computers, attitude toward instruction and time to learn. Results are reported in terms of the ES statistic as well as including information on the more traditional tests of statistical significance.

Forty-eight of the studies reported results from final examinations and in about 80% of these CAI students outperformed students who received only TI. Of the 25 studies in which statistically significant differences were reported, 23 or 92% favoured CAI instructed students.

The overall mean ES for all studies was .32, indicating that about 63% of the CAI students outperformed the average student from control or TI classes. Somewhat suprisingly, there were no statistically significant associations between study features and ES. The tendency for lower ability students to profit more from CAI was, however, apparent in the findings.

In four of five studies retention scores (over 2 to 6 month intervals) were higher for CAI students but the CAI-TI differences did not reach statistical significance.

In 8 of 10 studies CAI-instructed students' attitudes toward the subject being taught were more positive but the overall effect was very small (mean ES = .12).

In all four studies in which it was investigated, CAI instructed students had more positive attitudes toward computers and the effect was significant and substantial (mean ES = .61).

In all four studies in which students rated the quality of instruction, students receiving CAI gave more favourable ratings, but the effect was small (mean ES = .19) and not statistically significant.

Only two studies reported on the comparative amount of time students took to learn. In both cases there were significant time savings, 39% and 88%.

Kulik, C.C. et al (1984)

This meta-analysis covered 29 studies and was restricted to computer-based education provided for students enrolled in grades 1-6. Most studies (25 of 29) investigated D&P or tutorial CAI, the remainder were directed toward CMI.

The four CMI studies produced only a trivial mean ES of .07 and will not be described further in this review.

In every one of the 25 CAI studies using student achievement as the outcome measure, students in CAI classes outperformed the students receiving TI. In 20 of the 25 studies the differences were statistically significant and the average ES was .48, the equivalent of about 5 months on a grade equivalent scale.

In four studies, the average effect size was greater for low ability students.

In all four studies in which it was investigated retention was better for CAI students, with an average ES of .31.

Kulik reports that a meta-analysis by Hartley conducted in 1977 found an average ES of .41 for CAI supplemented mathematics instruction at the elementary and secondary level and that elementary students fared better than secondary students.

A meta-analysis of 59 CBE studies at the college level produced an average ES of .25 (Kulik, 1980).

Kulik generalizes from her own and other studies that CAI is increasingly effective as one goes from college to secondary levels and that, conversely, CMI is more effective as grade level increases. One rationale for this finding is that older students have less need of highly structured learning materials, immediate feedback and teacher control.

Generalizations

The five reviews of the literature reported above allow for the following generalizations:

- (1) Well designed and implemented D&P or tutorial CAI, used as a supplement to traditional instruction, produces an educationally significant improvement in students' final examination achievement.
- (2) Although the evidence is less convincing, students exposed to CAI supplemented traditional instruction probably retain the material learned slightly better than students receiving only traditional instruction.
- (3) When CAI is used as a substitute for traditional instruction, students will probably take less time to complete a course, i.e., CAI is probably a more efficient delivery system.
- (4) CAI is probably more effective with low ability or disadvantaged students than with average or above average students.
- (5) Although CAI has been shown to be effective at all levels, it appears to be relatively less effective as one goes from elementary to secondary to college levels.
- (6) Students exposed to CAI may develop more positive attitudes towards computers, instruction, and the subject taught.

Discussion

At this point in time it appears that CAI offers some promise of improving student achievement. The research literature is, however, silent on a number of important issues. There is no substantial research on micro-based CAI and very little programmatic research on the application of CAI to special education students. More importantly, there are no clear answers at present as to which particular features of CAI are responsible for its beneficial effects. Given the rapidity of hardware development and the uneven quality of research findings it is difficult, if not impossible, to assess the cost effectiveness of CAI. It is also apparent that the development of

high quality software is very expensive and that this, along with training and support service requirements, will limit the rate of expansion of CAI.

Given the current uncertainties about CAI and the substantial costs involved, it would seem wise to: (a) target its use very carefully (b) capitalize on existing high quality software whenever possible (c) build at least a minimal evaluation component into all new major applications of CAI and (d) monitor future research on micro-based systems very carefully.

Summary

In an attempt to assess the relative merits of CAI and traditional instruction, a search of the literature was conducted using the ERIC, PA, ONTERIS and ECER data bases. Of the 68 documents located and acquired, five were critical reviews of the literature and a summary of the findings of each is provided.

CAI shows some promise for improving student achievement and appears to have differential effects as a function of grade level and student ability.

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